LESSON 3 - TURN PERFORMANCE

The point of all maneuvering is to get into weapons parameters or out of an adversary's weapons parameters (if you made a mistake). A little pre-flight study can show you how to best be able to take or avoid the first shot.

Reading:

Shaw **pp. 86-89**, **pp. 387-417**
11-F16 **Sec 4.6.5.2 (pp. 46-53)**
Bretana pp. 8-11

Problems/Questions:

Work on Problem Set 1

Objectives:

3-1 Know how to calculate and what factors affect an aircraft's turn rate.
3-2 Know how to calculate and what factors affect an aircraft's turn radius.
3-3 Know the definition of corner velocity and how it affects an aircraft's combat performance.
3-4 Be able to compare an aircraft's turn performance in a level turn and a non-level turn.
3-5 Know the definitions of radial g and turn circle.

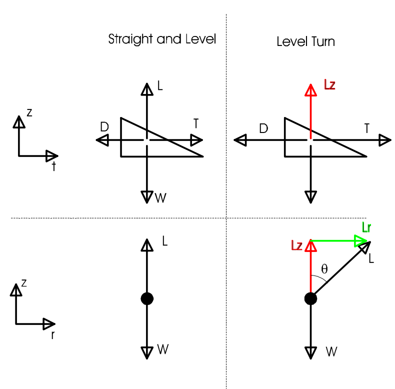
Last time: Maneuvering = accelerating
Combat accelerating controlled by stick alone
Sustained turn, $T \geq D$
Instantaneous turn limited by stall/structure

Today: Turn Performance
Rate/Radius
Level vs. Oblique

Equations: $r \propto v^2/G_r$, $\omega \propto G_r/V$

Show Ritchie quote, Physics of Flight, side B, frame 45874

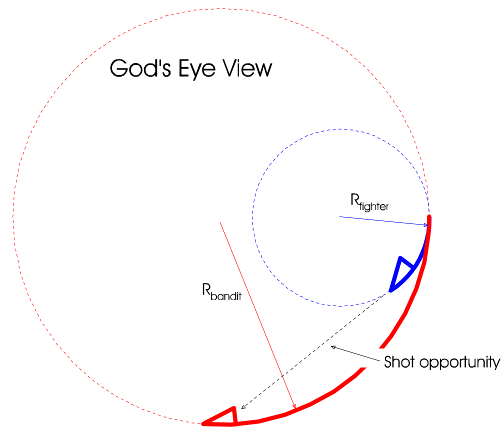
Review Turns



Only L_r causes the turn – it's the only unbalanced force

$\Sigma F_r = ma_r$ a_r = centripetal acceleration = v^2/r => $\Sigma F_r = L_r = mv^2/r$
$L/W = n \equiv G$, $L_r/W = G_r$, $W = mg$
$G_r = (mv^2/r)/(mg) = v^2/rg$ => $r = v^2/G_r g$,   or $r \propto v^2/G_r$

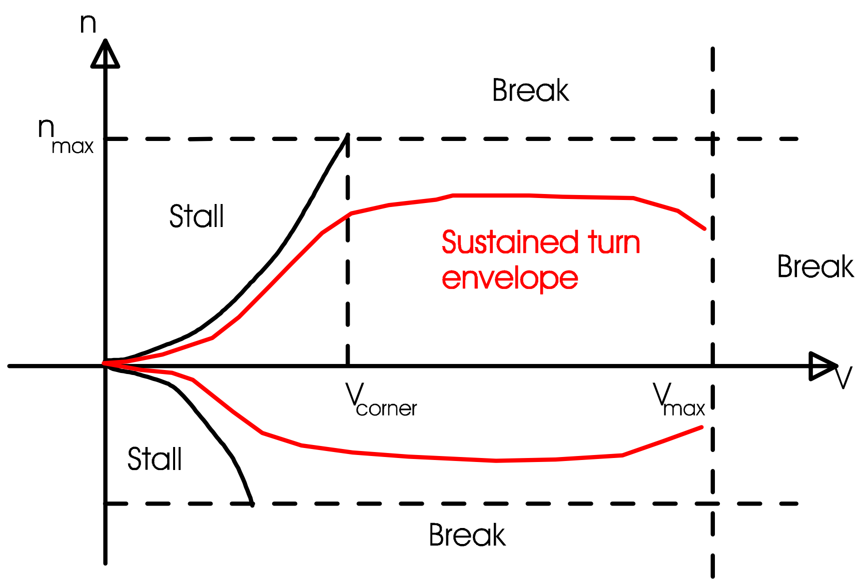
Now, we would like a small turn radius so we can turn inside the bandit

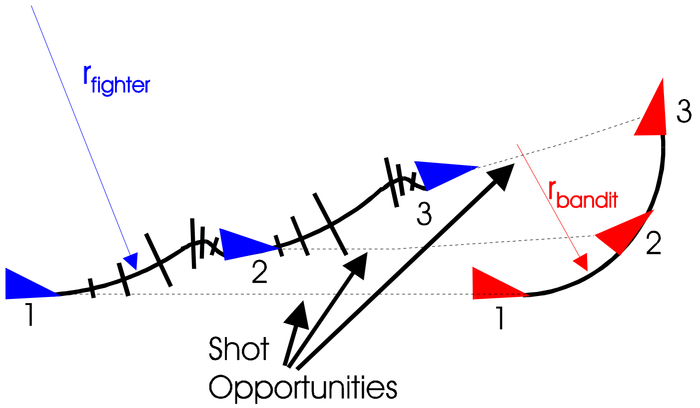


(Show with sticks)

How to minimize r: V↓, G_r↑

Show V-n diagram. If you slow below corner velocity, V↓ (good), but G_{r_max}↓ (bad) => r↑. If you fly above corner, V↑ (bad) and G_{r_max} stays the same (neutral), => r↑.



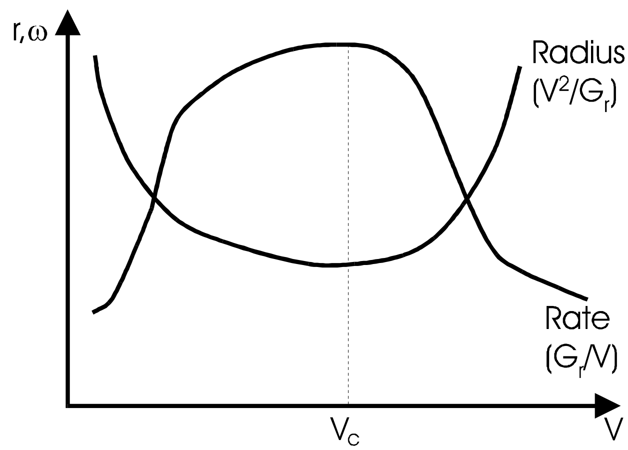


Radius is not the only important concept. What if r = small, but you can only turn slowly? (Show with sticks)

A slow rate allows the attacker to reposition, even with a larger radius.

How do we find ω?
θ = s/r (what if s is all the way around the circle? Show that for s=2πr, θ = 2π)
v = ds/dt, w = dq/dt = d/dt (s/r)
= (1/r)(ds/dt) = v/r
ω = v/r

but $r \propto v^2/G_r \Rightarrow \omega \propto v/(v^2/G_r)$
$\Rightarrow \omega \propto G_r/v$



Again, looking at the V-n diagram, we see that corner gives the best turn rate as well as the best turn radius. Corner be da place! A chart from the air to air handout shows this as well…

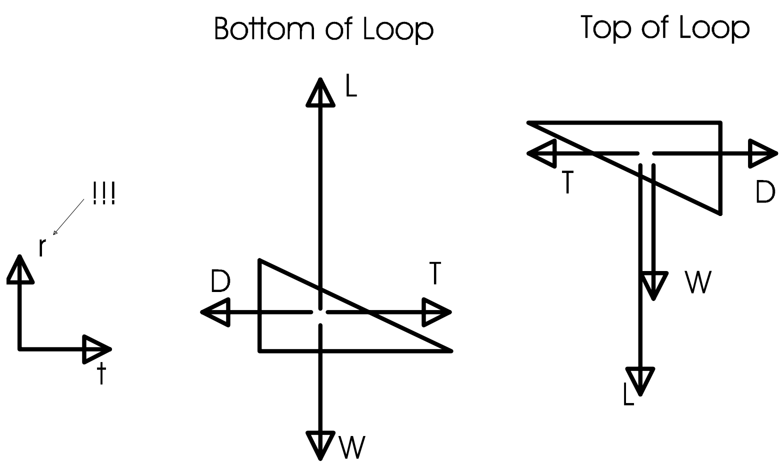
HOWEVER…….
Corner is only the place where you get the best INSTANTANEOUS performance and is not generally sustainable.

Show V-n diagram with sustained turn overlays

Let's switch gears and look at non-level turns. Specifically, let's look at the extreme version of this, a turn in the vertical plane.

Remember, it's radial G that turns the aircraft. If we're turning in the vertical plane, and we're starting from straight and level flight, which way is the radial direction?

Newton's law in the radial direction at the bottom of this loop is
$\Sigma F_r = ma_r = mv^2/r$. recalling $G_r = v^2/rg \Rightarrow gG_r = v^2/r$, so Newton II becomes $\Sigma F_r = mgG_r = WG_r$. The forces acting on the jet in the radial direction are L-W, so L-W = WG_r, or G_r = (L-W)/W = L/W - W/W, but since L/W = n, at the bottom of this loop, G_r = n-1.



What does this mean? What acceleration is turning the jet? G_r. What acceleration limits how much you can pull? n. This means that if you pull 4 Gs, you only get 3G turn performance. BAD!

At the top of the loop, things are a bit different. Here, the forces sum to L+W, so L+W = WG_r, implying by the same reasoning that at the top of the loop, G_r = n+1, a much better situation. If you pull 4Gs, you get 5G turn performance.
Any time your bank angle is greater than 90 degrees, your turn performance will increase as you use "God's G" as a turning assist. In reality, your airspeed is NOT constant, so G_{max}, w_{max}, and r_{min} vary even more!

Show Physics of Flight side B frame 34771 (F-16 HUD view of a constant G loop)

Point out the different turn rates at different points in the loop.